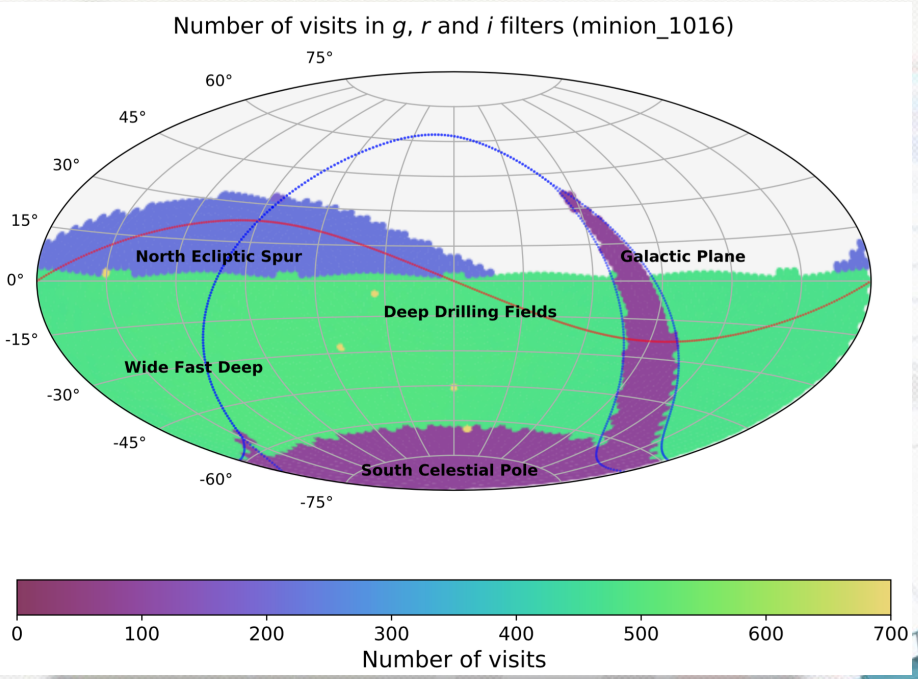
LSST Plans for Cadence Optimization

Željko Ivezić, Lynne Jones, LSST Simulations and Scheduler Teams

LSST PST and Science Collaboration Chairs Telecon

May 30, 2017



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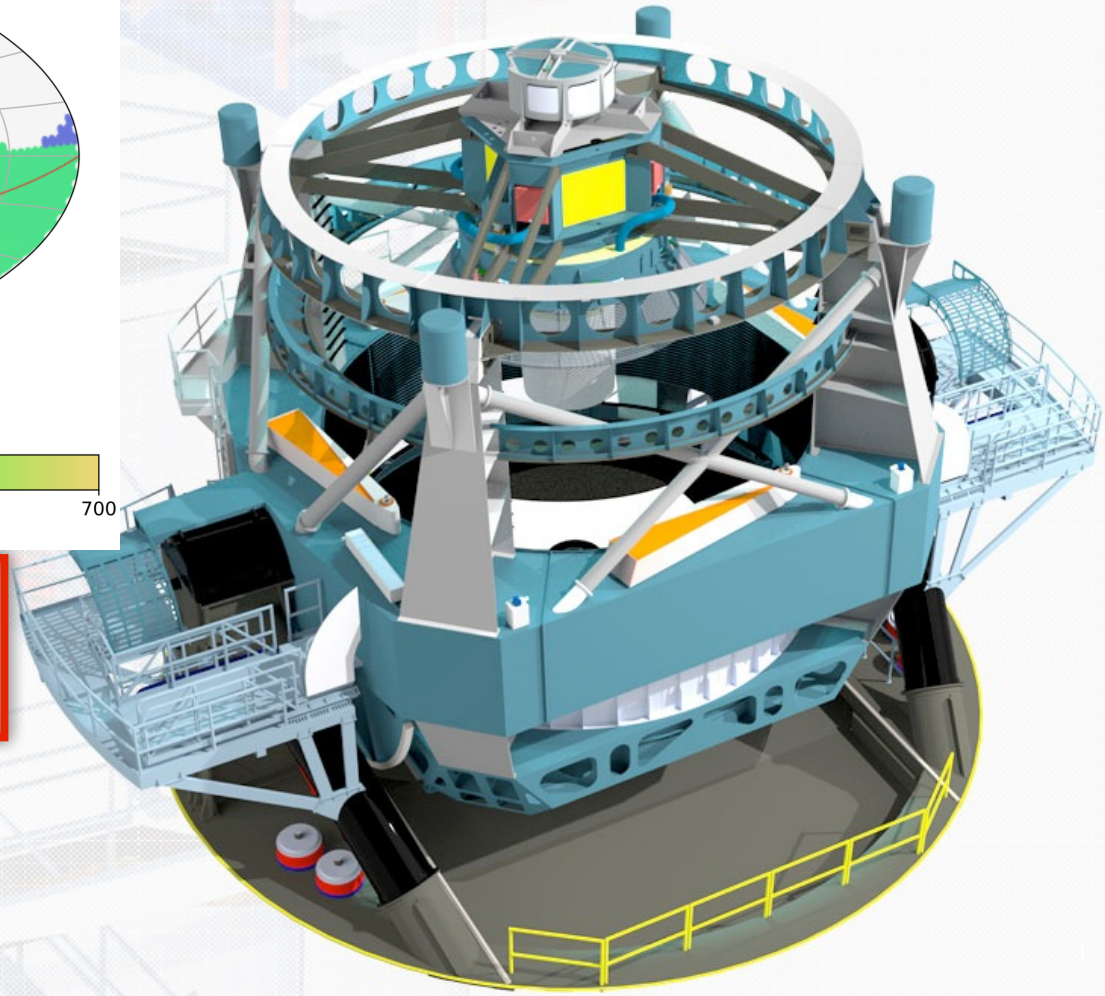

Outline

1) Brief overview of cadence work done in 2016/17

- adopted new baseline cadence
- cadence exploration and optimization
- towards OpSim4 and rolling cadence

2) Where are we now

- SOCS/Scheduler Development Schedule
- Observing Strategy white paper: lessons learned
- improvements in organization and new resources

3) What are we planning to do over the next 3 years (~ until commissioning starts)

- plans for cadence optimization program
- open questions for considerations by the community

Recent presentations about the LSST observing strategy and related topics:

1) **Presentation to the SAC about LSST Observing Strategy (2015):**

Available as:

http://ls.st/4yh

2) **Talks at the Observing Strategy Workshop (Bremerton, 2015):**

Andy Connolly: "LSST Operations Simulator"
Peter Yoachim: "Metrics Analysis Framework"
Zeljko Ivezic: "Review of science-driven cadence optimization to date"

Available at:

http://ls.st/kaq

3) **Presentations to the SAC (March 2017):**

http://ls.st/jzm

Loaded with information but will not be repeated here: instead, focus here on recent updates

Presentation to the SAC about the LSST observing strategy (Nov 2015):

1) Brief overview of tools for simulating LSST surveys: OpSim & MAF

2) Why is survey optimization a hard problem: hierarchy of survey complexity

3) What can and cannot be done? Cadence "conservation laws"

4) Examples of cadence optimization and future optimization directions.

5) The community and SAC role in advising the Project on cadence-related decisions

Available as:

http://ls.st/4yh

Cadence improvements

Drivers for baseline cadence modifications:

- improved knowledge of the system (now due to simulations, eventually due to performance measurements)
- changing science landscape on timescales of a few years
- unscheduled technical delays or substandard performance (e.g. broken filter, dead CCD, extra noise)
- even 10% improvement in surveying efficiency would be significant accomplishment (c.f. > entire DD time)
- improved time-domain programs
- improved special programs

We must construct a sufficiently flexible system that will be able to respond to unexpected and re-optimize the survey.

Potential optimization directions:

- **optimizing exposure time** (e.g. minimizing the impact of read-out noise in u band, abandoning snaps, twilight)
- **optimizing sky coverage** (WFD: area vs. coadded depth, Galactic plane, south celestial pole, LMC/SMC, Ecliptic)
- **temporal sampling** (SNe, variable stars, asteroids)
- **rolling cadence** (interplay between sky coverage and temporal sampling)
- **deep drilling fields**
- dynamic cadence (in response to expected SNR)
- evolving cadence (in response to science drivers)

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Proposals from the community and PST

For input from the community, see

http://ls.st/smg

Tier 2 (miscellaneous, not NEO, not rolling cadence)

2.1 Target of Opportunity Observations

2.2 WFIRST coverage over 2,300 sq.deg. in 5 years

2.3 Extend WDF to the Galactic Plane (n.b. smooth northern Dec limit)
(NEO optimization separately in Tier 3)
(SNe rolling cadence separately in Tier 4)

2.4 No snaps in a visit (a block exposure of 30 sec, no readout after 15 sec)

2.5 Utilizing twilight time (Stubbs' proposal, needs sky brightness model)

Tier 3: NEO-optimized runs

Adopted new Baseline (minion_1016) OpSim3

Basic characteristics (see http://opsim.lsst.org:8080):

- the total number of visits is 2.45 million, with 85.1% spent on the Universal proposal (the main deep-wide-fast survey), 6.5% on the North Ecliptic proposal, 1.7% on the Galactic plane proposal, 2.2% on the South Celestial pole proposal, and 4.5% on the Deep Drilling proposal (5 fields)

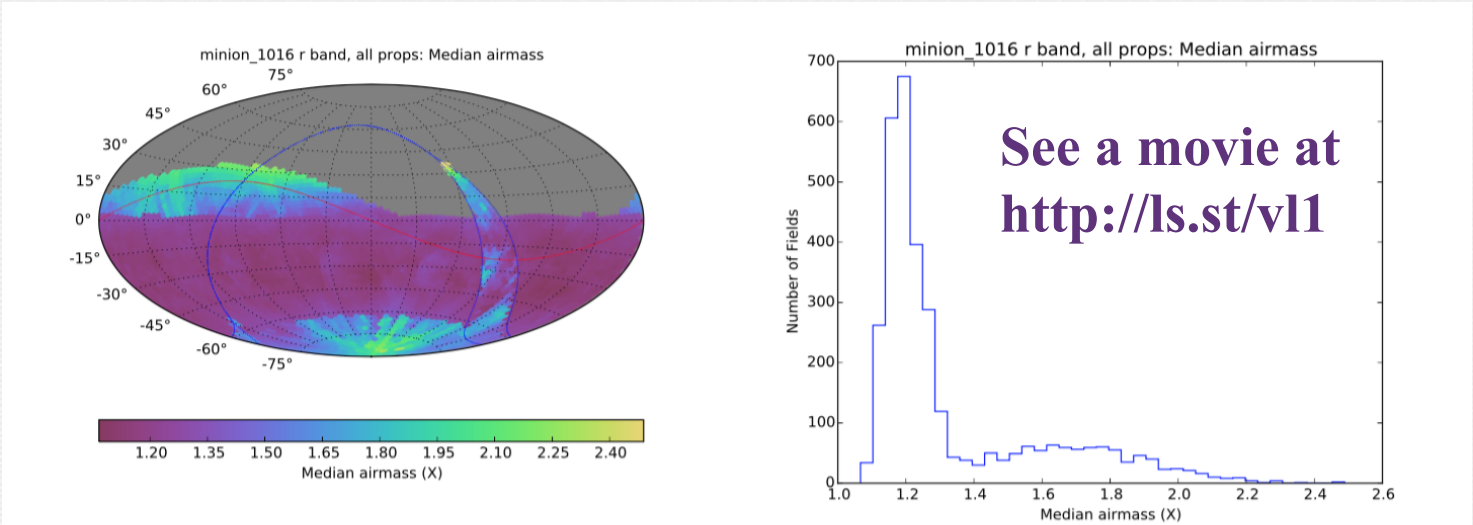
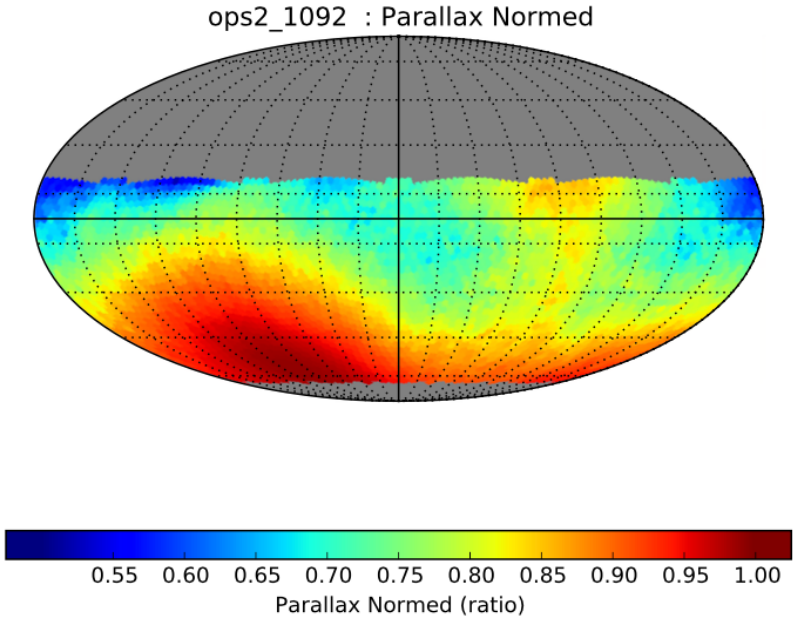


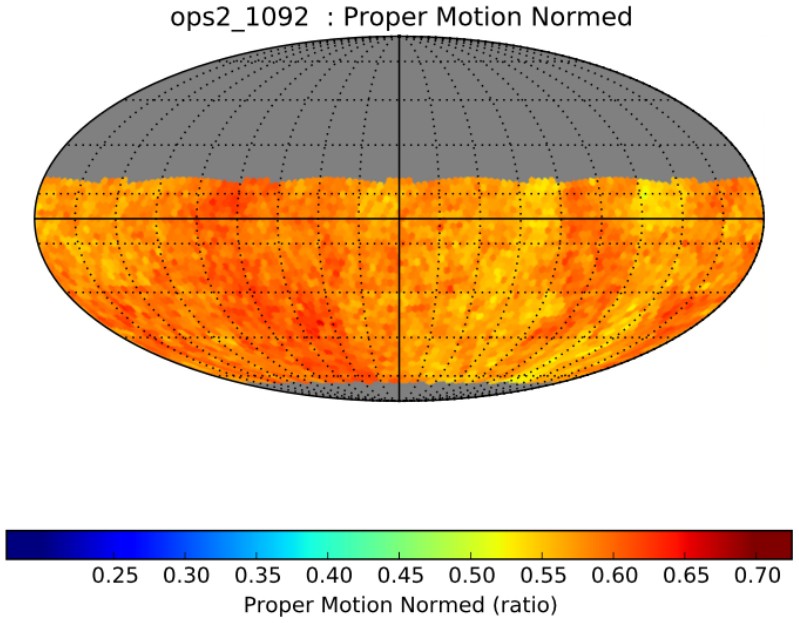
Figure 2.1: The median airmass in the r band across the sky for simulated cadence `minion_1016` is shown in Aitoff projection of equatorial coordinates in the left panel. The red line shows the Ecliptic and the blue line shows the Galactic equator. The blue curve splits to enclose the so-called "Galactic confusion zone". The corresponding airmass histogram is shown in the right panel. For the main survey area, the maximum allowed airmass was set to 1.5.

Sky coverage vs. depth tradeoff for WFD survey

Should we simply apply Universal Cadence everywhere?

If you are interested in trigonometric parallax and proper motions, it certainly looks nice! Note, though, that the Galactic Plane may not be that good due to crowding issues. (also good: self-calibration, legacy,…)

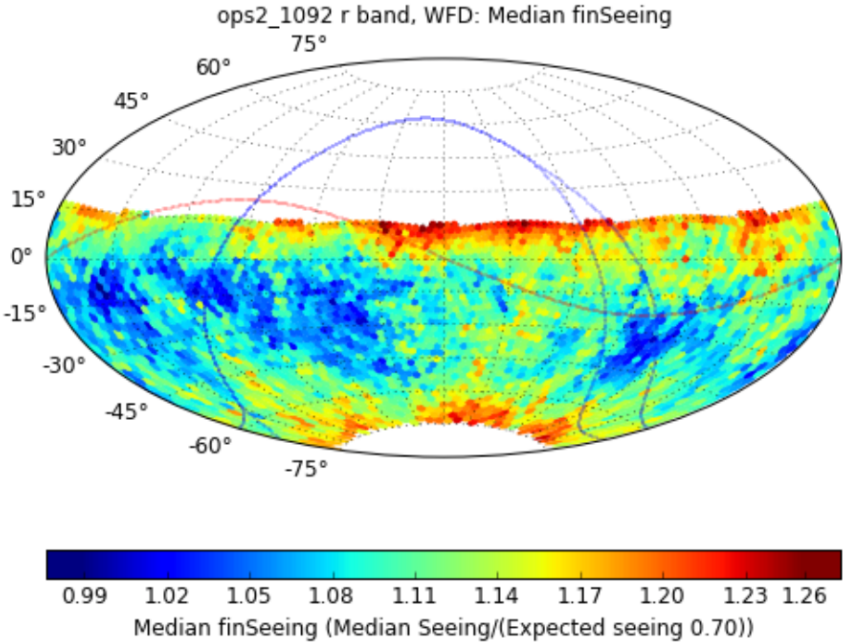


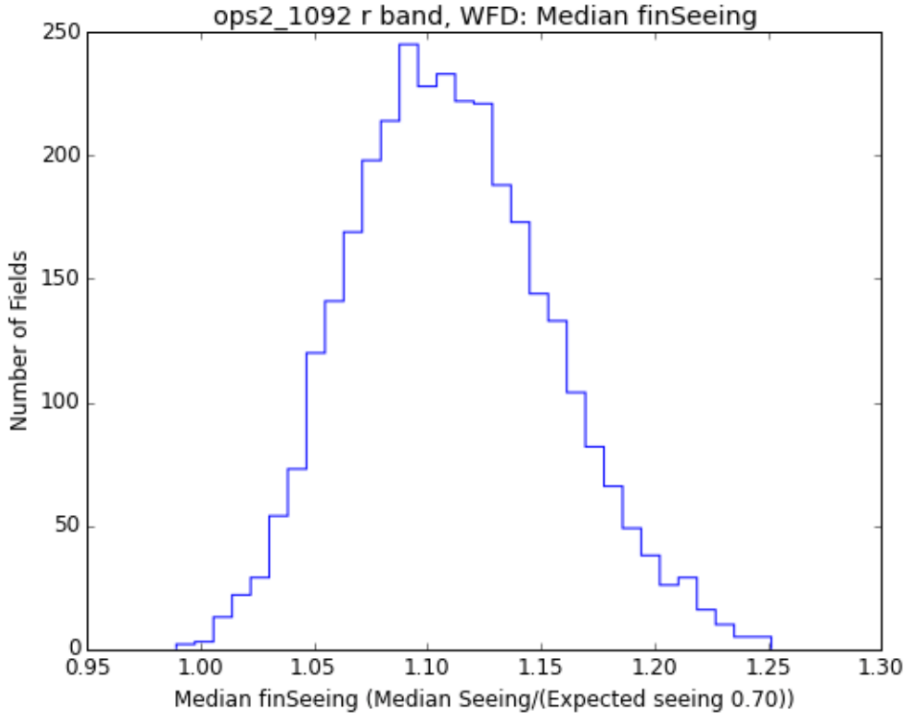


Sky coverage vs. depth tradeoff for WFD survey

Should we simply apply Universal Cadence everywhere?

If you are interested in maximizing the counts of "effectively resolved" galaxies (for WL), the total count of galaxies is similar as in Baseline Cadence:

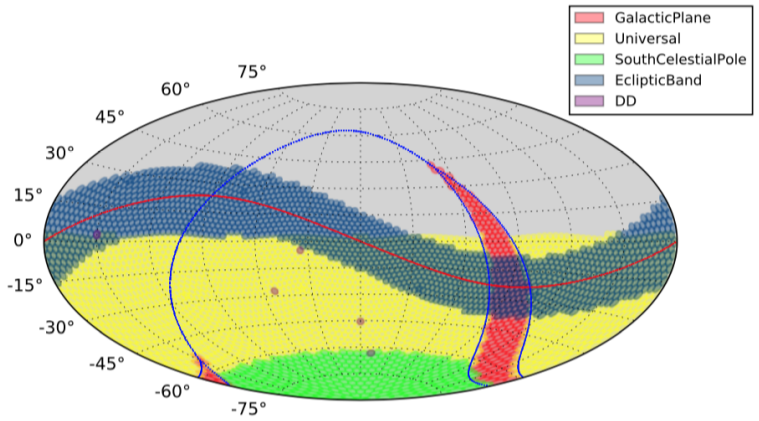




NEO cadence improvements (Tier 3)

Main accomplishments:

- a series of NEO-optimized cadences produced and analyzed
- a paper on "The LSST as a Near-Earth Object Discovery Machine" by Jones et al. submitted to Icarus
- a joint report with a NASA-funded JPL group (Chesley & Ivezic) submitted to NASA NEO Office in January 2017



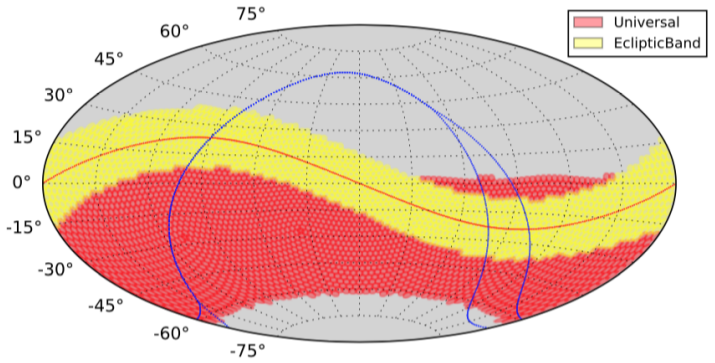


Fig. 7.— The footprints of the proposals, including the Ecliptic Band proposal, used in the NEO-optimized simulated surveys astro_lsst_01_1015 (the "longer ecliptic visits" survey, left) and astro_lsst_01_1017 (the "NEO-focused" survey, right). The astro_lsst_01_1017 survey only includes two proposals.

Towards OpSim v4 and rolling cadence

Main drivers for non-uniform, more frequent, visits:

- supernovae: need about three times higher sampling rate
- asteroids: tracklet linkage would be easier
- short-period variability (e.g. cataclysmic variables)

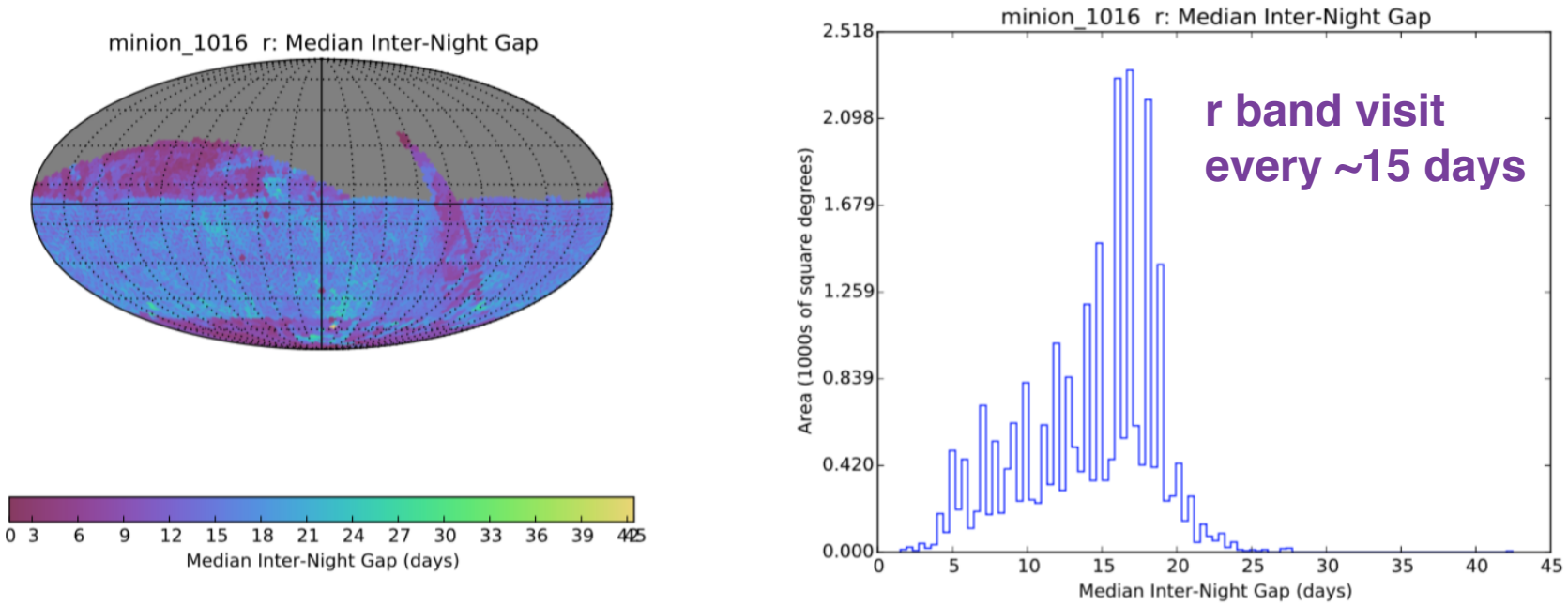


Figure 2.9: The median inter-night gap for r band visits is shown in Aitoff projection for all proposals and all filters for candidate Baseline Cadence minion_1016. On average, fields in the main survey get revisited in the r band about every two weeks.

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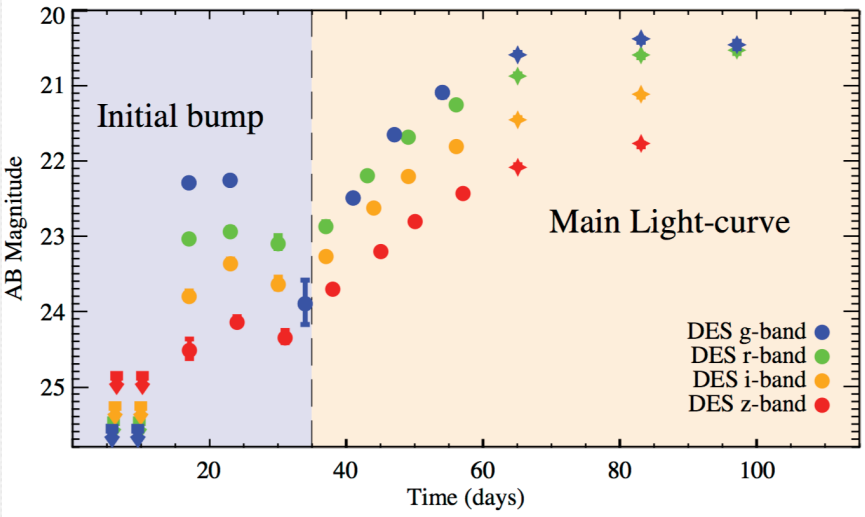
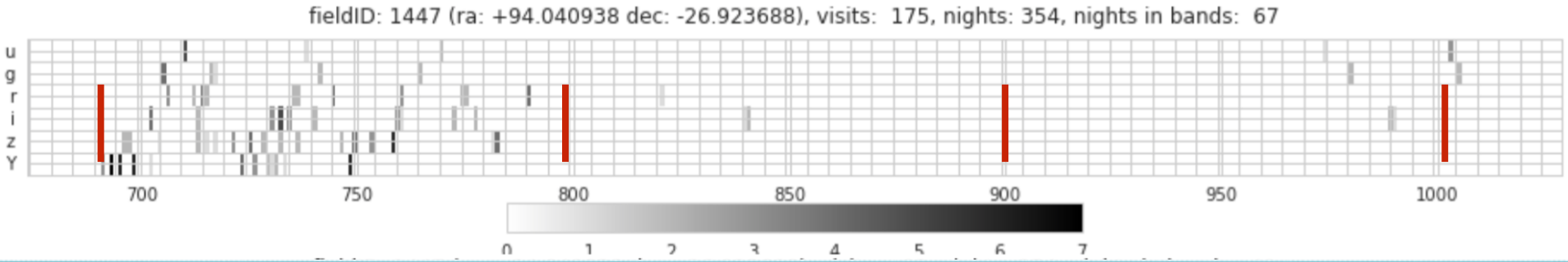


Left: light curve for supernova DES14X3taz (Smith et al. 2016)

To resolve pre-peak bump, need revisit rate of ~5 days.

Bottom: an illustration of an LSST rolling cadence implementation (Andy Connolly and Rahul Biswas)



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SOCS/Scheduler Development

- SOCS/Scheduler v1.0 (aka OpSim4) beta released in Feb 2017; OpSim4 validation has not been completed yet.

- v1.0 supports rolling cadence (and fixes a number of earlier problems, e.g. the so-called “western bias”)

- for detailed SOCS/Scheduler development plan (old dates but release content is correct), see

http://ls.st/7qv

- SOCS/Scheduler v2.2 (the last release) released by the end of 2020 (NB the release schedule might be revised)

- SOCS/Scheduler release schedule drives in part the cadence optimization program

Motivation and goals for a white paper on "Science-Driven Optimization of the LSST Observing Strategy

https://github.com/LSSTScienceCollaborations/ObservingStrategy

The baseline cadence may not be the best way to deploy the LSST system.

The baseline strategy is not set in stone, and can be improved.

Even small changes could result in **significant improvements** to the overall science yield.

How can we design an observing strategy that maximizes the scientific output of the LSST system?

The LSST Observing Strategy community formed in July 2015 to tackle this problem.

Motivation and goals for a white paper on "Science-Driven Optimization of the LSST Observing Strategy

https://github.com/LSSTScienceCollaborations/ObservingStrategy

Through the end of construction and commissioning, this community Observing Strategy White Paper will remain a ***living*** document that is ***the*** vehicle for the community to communicate to the LSST Project regarding the Wide-Fast-Deep and mini-survey observing strategies.

The Project Scientist will **synthesize and act** on the results presented in this paper, with support from the Science Advisory Committee and Survey Strategy Committee.

As described in the LSST Operations Plan (in progress), the observing strategy will continue to be refined and optimized during **operations**.

Lessons learned from "The ten cadence questions"

LSST Observing Strategy White Paper considers **a large number of LSST science cases** that cover all major science themes to provide guidelines for improving baseline LSST cadence (~300 pages by ~100 authors).

In order to standardize various constraints derived from diverse science cases, **ten questions about cadence were formulated** and provided to all authors.

Detailed answers were provided for 20 major science cases; 76 answers provided actionable input.

Conclusions derived from those answers are listed in a document provided to the SAC, and are only briefly summarized here.

Lessons learned from "The ten cadence questions"

1)The Project should implement, analyze and optimize the **rolling cadence** idea (driven by supernovae, asteroids, short timescale variability).

2) The Project should execute a **systematic effort** to further improve the ultimate LSST cadence strategy (e.g. sky coverage optimization, u band depth, special surveys, DDFs).

Main Conclusions

The LSST Observing Strategy community and the white paper effort are providing exceedingly useful guidance about cadence to the Project (many thanks to Phil Marshall for his leadership!)

While **baseline cadence** meets the basic science requirements for the LSST survey, we know that it **can be meaningfully improved!**

In part as a result of these recommendations, the Project decided to reorganize and re-energize the cadence improvement efforts:

1) New hires for the Scheduler development in progress

2) A new dedicated postdoc (Owen Boberg) to work with Lynne Jones and Zeljko Ivezic on cadence optimization (including interactions with the community)

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- open questions for considerations by the community
- plans for cadence optimization program

The role of the SAC and community in advising the Project on cadence-related decisions

1. We need to define quantitative science drivers for the observing strategy of the LSST (e.g. the depth and filters required for early science; the sky region, cadence and number of filters required to “measure something”).
   The SRD is intentionally vague on these details!

For example, is 10% of observing time dedicated only to deep-drilling programs or to all non-WDF programs (e.g. Galactic plane)?

Per SRD, 90% of the total time goes for WFD, and 10% for everything else. If the system will perform better than expected, or if science priorities will change over time, it’s conceivable that 90% could be modified and become as low as 80%. But at this time, it’s 90% for WFD and 10% for everything else, as codified in the SRD.

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2. To express these drivers in terms of “metrics” by which the science returns (simulated surveys) can be quantified

3. To define the (OpSim) experiments needed to develop and test these metrics so that we can determine how much science is gained or lost as a function of the current survey strategy or future modified strategies

The role of the SAC and community in advising the Project on cadence-related decisions

Example questions that are hard to answer:

1. Quantitative science drivers:

   - an example: the proposal to extend WFD survey to the Galactic plane (Gould, A. 2013, arXiv:1304.3455)

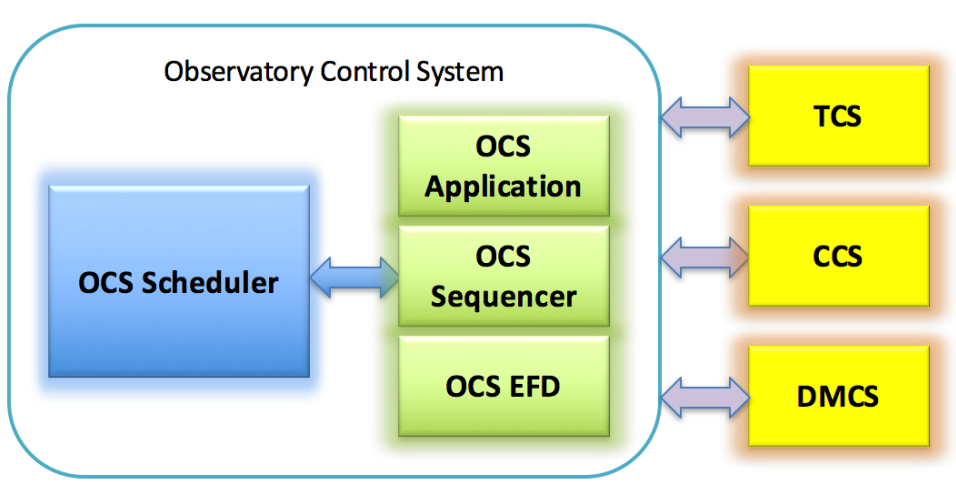
   Is the anticipated science worth 10% of LSST?

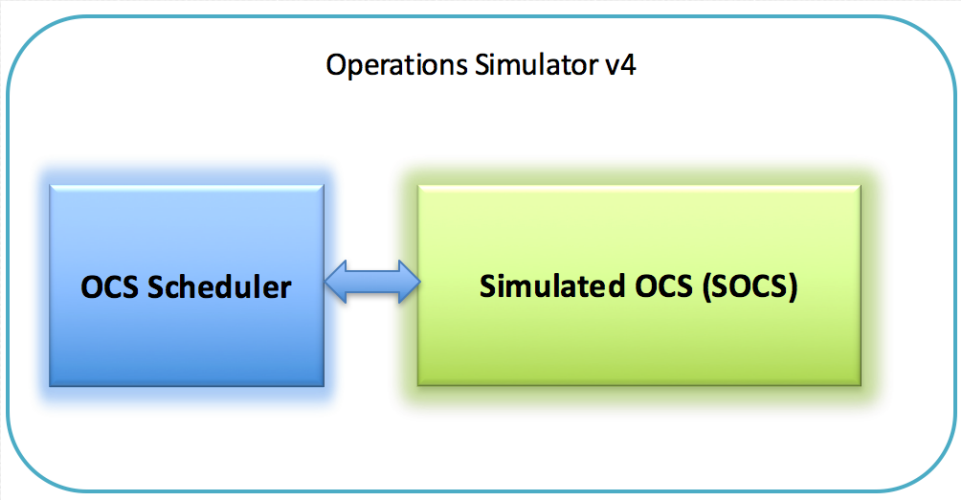
2. Metrics:

   - an example: how does a 10% improvement in “early SNe” metric compare to a 10% improvement in proper motion metric?

3. OpSim experiments: we don’t have infinite resources; for example, which X% of proposed modifications shall we study?

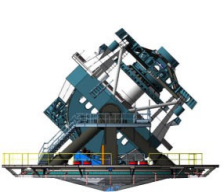
Plans for the cadence optimization program

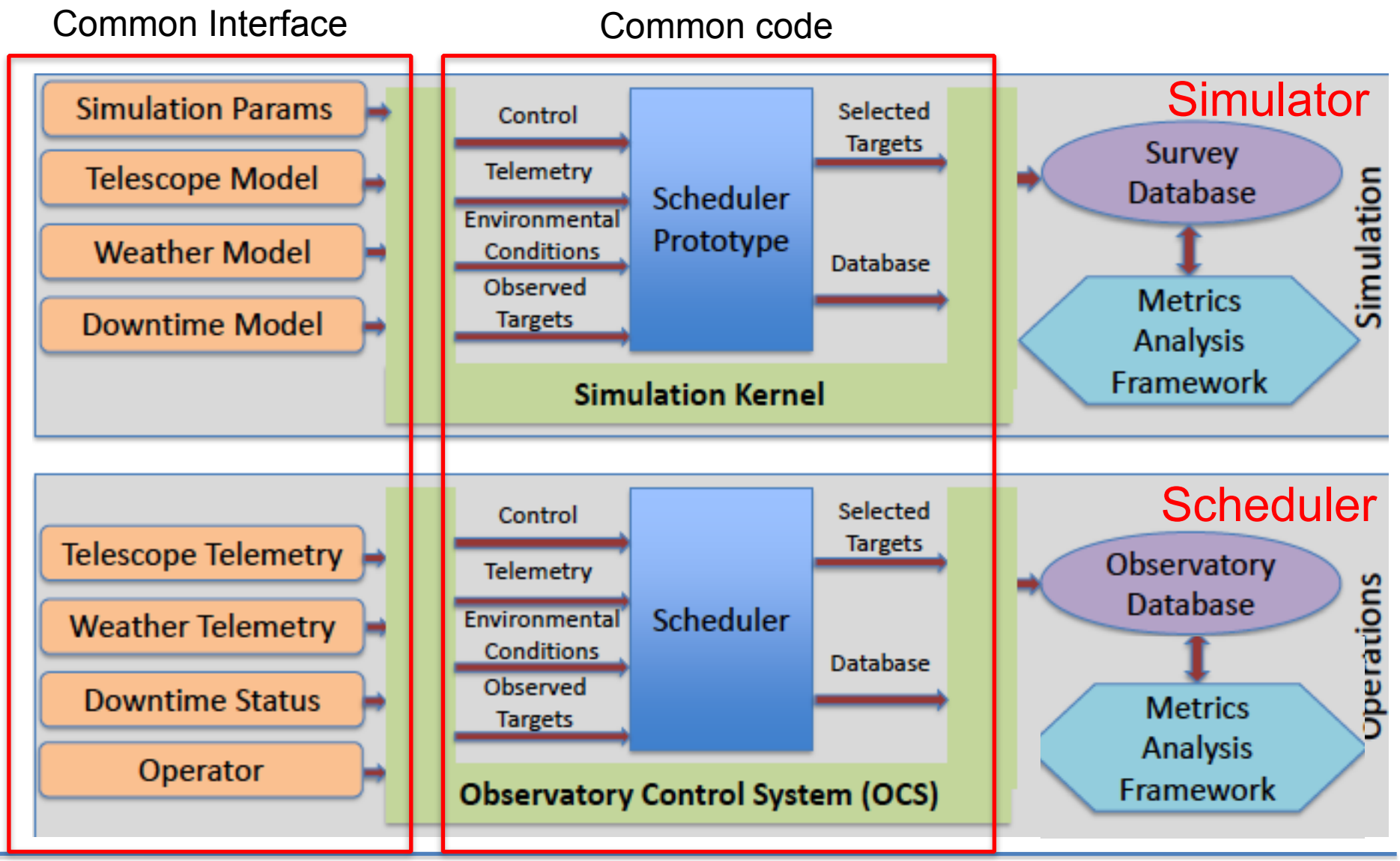




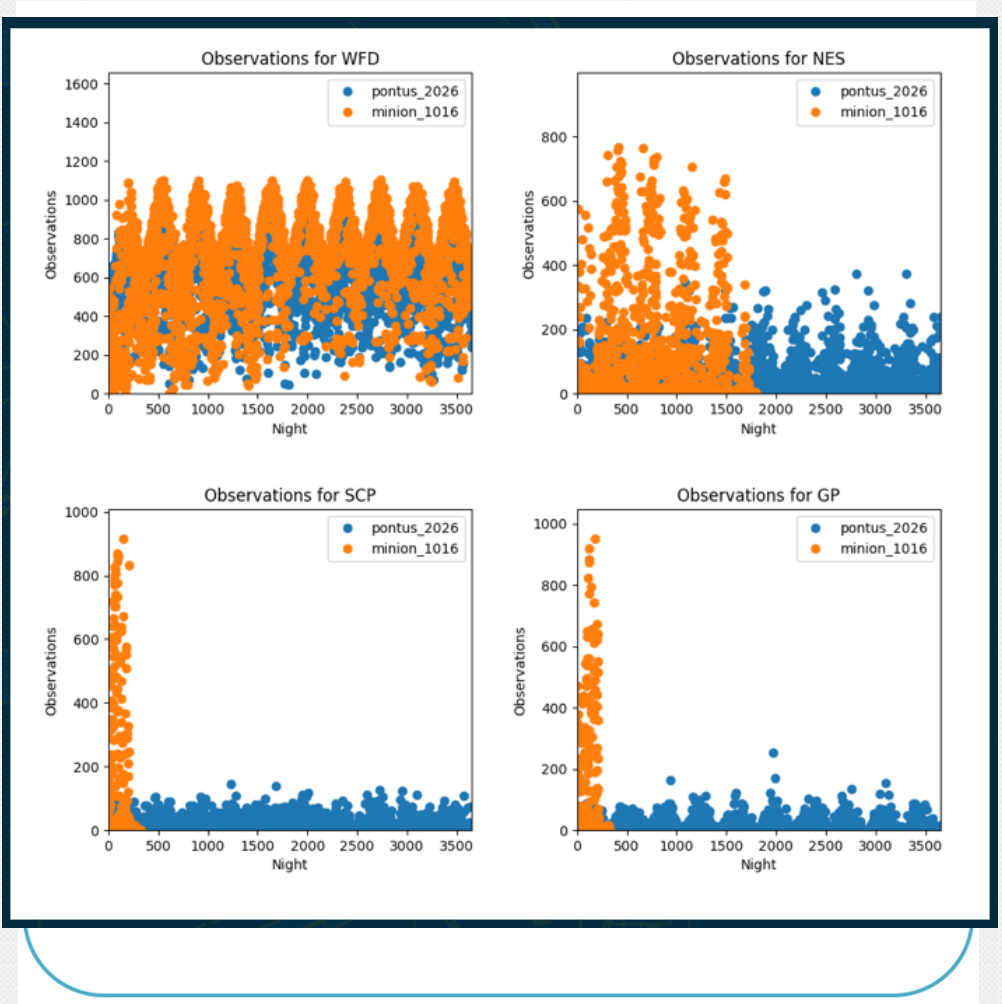
- the piece of code that drives OpSim, called **the Scheduler**, will also be a part of the Observatory Control System: T&S deliverable

Scheduler/simulator Interface





Plans for the cadence optimization program



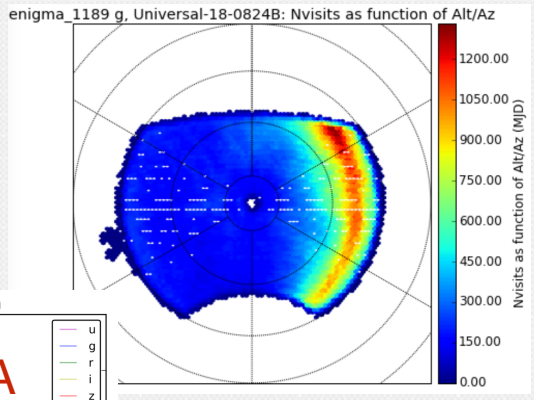
- the piece of code that drives OpSim, called **the Scheduler**, will also be a part of the Observatory Control System: T&S deliverable
- the Scheduler v1.0, which is part of OpSim4, was just released:

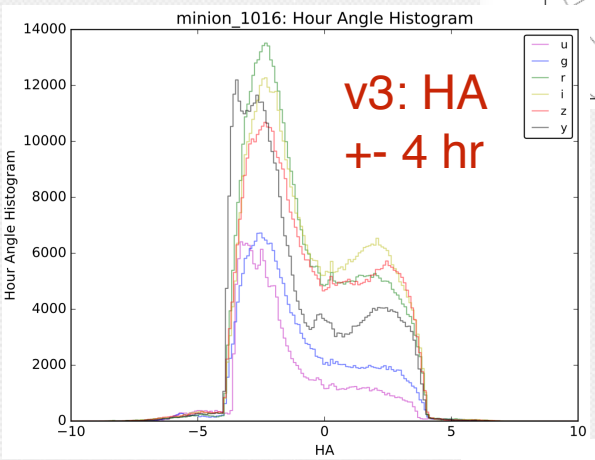
Main improvements v4 vs. v3:

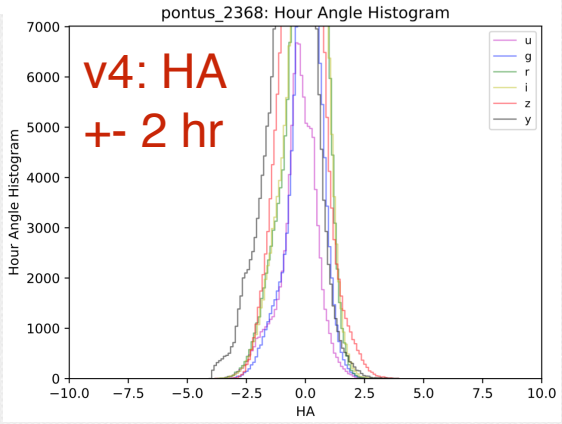
- Better time uniformity
- Repeatability over full 10 year survey with same configuration
- Sky region selection using coordinate cuts
- New sky brightness model (ESO, includes twilight)
- Separate instances of Observatory model for SOCS and Scheduler
- Configuration Parameter User Interface

Plans for the cadence optimization program

v4 fixed the "western bias" problem:







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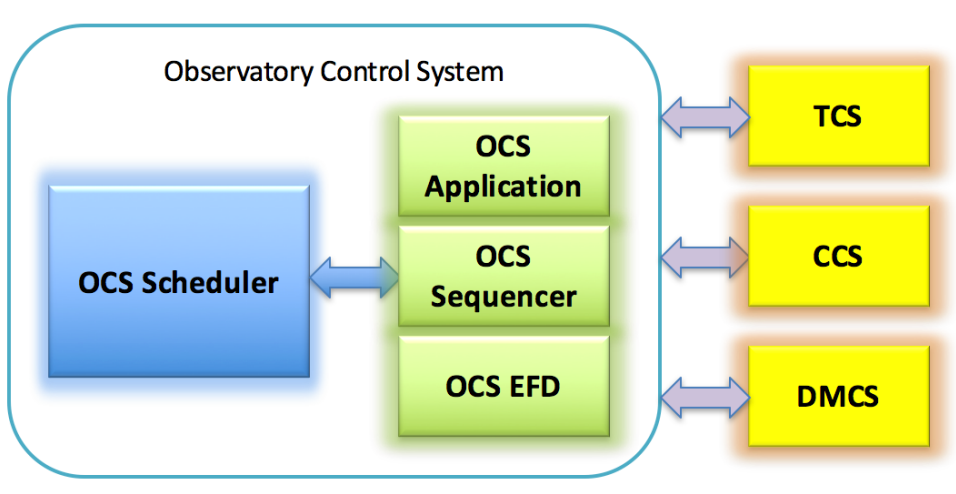

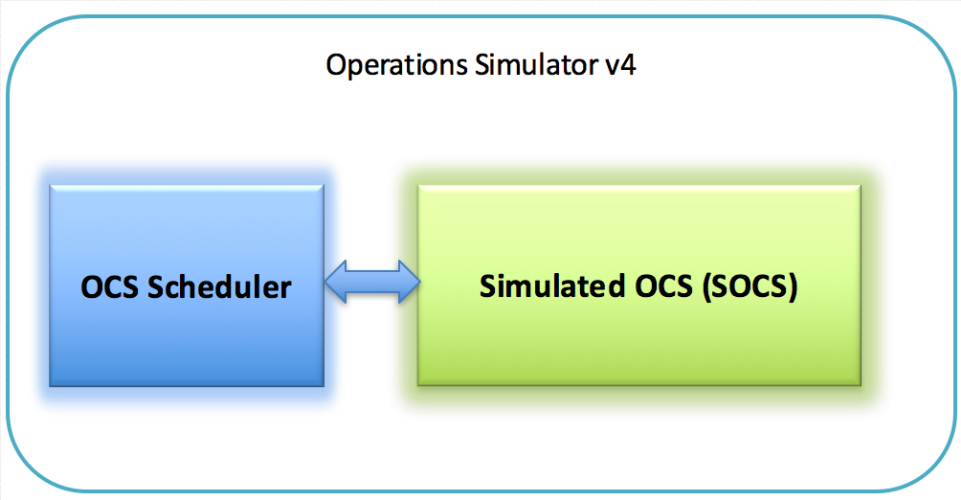

- the piece of code that drives OpSim, called **the Scheduler**, will also be a part of the Observatory Control System: T&S deliverable
- the Scheduler v1.0, which is part of OpSim4, was just released
- in addition to numerous bug fixes and improvements, it now enables simulations of **rolling cadence**
- another eagerly anticipated version is v1.2 (by mid 2018): it will deliver the so-called "look ahead" feature (will a field set before the pair is completed?)
- the last release, v2.2, expected in early 2021, will enable other scheduling algorithms

Plans for cadence optimization program

- separation of 1) SW engineering and delivery of the Scheduler code by the T&S Scheduler team from 2) interaction with the community and cadence optimization efforts under Project Office

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- development of the code by the T&S team can be adapted to new requirements or findings in the process of interaction with the community; to address that posibility the project has a Change Request process in which the proposed changes are evaluated in cost and schedule and may be eventually incorporated as changes in the release plan (presented below)

Plans for cadence optimization program

- separation of 1) SW engineering and delivery of the Scheduler code by the T&S Scheduler team from 2) interaction with the community and cadence optimization efforts under Project Office

- three **logical** phases for the cadence optimization program

  1) develop tools (running OpSim at scale & MAF improvements) that will enable production and analysis of hundreds of simulated cadences

  2) interact with the community and stakeholders:

  - **call for DDF white papers: Dec 2017 (due Apr 2018)**
  - **call for mini-surveys white papers: Oct 2018 (due Feb 2019)**

  and finalize the definitions of cadences for WFD, DDF and mini-survey programs

  3) produce, analyze and document a judiciously chosen series of cadences and present to the SAC for a final strategy recommendation (by May 2020)

Important: we anticipate many iterative interactions towards convergence with the community rather than a requirements-to-deliverable model.

Schedule for Cadence Optimization

	Scheduler/SOCS dev.	Cadence Optimization	Calls to Community
2017	**v1.0** Repeatability, New sky brightness model, Time uniformity, Rolling cadence capability	Start work on tools to run MAF & Opsim at scale	
	v1.1 Nondeterministic weather & downtime, Deterministic lookahead for Area Distribution proposals	Rolling cadence experiments; DDF experiments/examples	Publish Observing Strategy white paper (OSWP) Call for DDF white papers (Dec)
2018	**v1.2** Deterministic lookahead for Time Distribution proposals	Rolling cadence experiments evaluated with OSWP metrics; Mini-survey experiments/examples	DDF white papers due (Apr)
	v1.3 Performance improvements	DDF WP -> simulated surveys; mini-survey experiments	Call for mini-survey (special programs) white papers (Oct)
2019	**v1.4** Warm start, IQ feedback, degraded operational modes	Updated baseline with DDF + rolling cadence (June)	Mini-survey white papers due (Feb) Request for white paper and metrics update (Mar)
	v1.5 Spatial distribution for weather, Dithering support in scheduler	Mini-survey WP -> simulated surveys;	White paper with metrics due (Aug)
2020	**v2.0** Publication of future targets within ~2hr window	Finalize MAF and Opsim tools; deliver documentation and a series of simulated surveys to SAC; form SSC	
	v2.1 Weather forecast in lookahead	Ask SAC and Survey Strategy Committee to recommend the initial observing strategy	
2021	**v2.2** Generic interface for optimization algorithms, incorporate community provided optimizations	Announce initial survey strategy and publish a baseline simulation that reproduces that strategy	

Recommended means for providing input about LSST cadence

- the LSST Science Advisory Council (SAC) is the main mechanism for officially collecting and delivering community input to the Project. All strategic and political issues should be communicated via SAC (Michael Strauss).
- to enable an open and archived discussion, we will setup a “category” on community.lsst.org
- for concrete cadence modification proposals, please use the form at http://ls.st/smg
- the LSST Project Scientist is responsible for cadence optimization efforts and is the formal liaison between the community and the LSST Scheduler/OpSim teams (chairs PST and reports directly to the LSST Director); please feel free to email with any questions you might have (ivezic at astro.washington.edu)

SAC, community.lsst.org, webform and Zeljko

Summary

1) OpSim4 (Scheduler v1.0) was recently released and it now supports the "rolling cadence" strategy (needs validation)

2) The 2017 community-led Observing Strategy white paper provided exceedingly useful guidance to the Project

3) The Project has identified new resources to undertake a cadence optimization program over the next 3 years

4) The community will play a major role in this program

5) The Science Advisory Committee will be asked to make an informed decision about the final observing strategy

6) The Project invites your input via: Obs.Strategy white paper, SAC, cadence webform, community.lsst and Zeljko